

Effectiveness of Everglades Agricultural Area Best Management Practices for Total Nitrogen Reduction

**Prepared for: Department of Agriculture and Consumer Services,
Office of Agricultural Water Policy**

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January 2015



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EXECUTIVE SUMMARY

The Everglades Forever Act, Section 373.4592, F.S., requires the South Florida Water Management District (SFWMD) to implement a permitting program to authorize discharges, subject to conditions or requirements, from landowners within the Everglades Agricultural Area (EAA). Chapter 40E-63, F.A.C., provides for the implementation of this Everglades Program, including defining the requirements for Best Management Practice (BMP) research, testing, and implementation to address water quality standards. Numerous studies (*e.g.*, McCafferty *et al.* 2015) have demonstrated that the BMPs implemented within the EAA have been very effective in reducing the TP load.

The Dept. of Agriculture and Consumer Services, Office of Agricultural Water Policy, has established a strategic objective to confirm BMP effectiveness. The purpose of this report was to analyze the effectiveness of EAA BMPs for Total Nitrogen (TN) load reductions.

The Everglades Forever Act mandates a 25% reduction in TP loading between what the Act defines as the “baseline period” (1980-1988) and the period of “full BMP implementation” (1996-2014). The analysis presented in this report demonstrates that there has been a **40.4% reduction in TN loading** between these two time periods. Additionally, the water quality of the EAA discharge has been more consistent (less variable) after full application of BMPs (**Figure 1**).

Typical Best Management Practices for the EAA Basin consist of Nutrient Control Practices; Water Management Practices; Particulate Matter and Sediment Control; Pasture Management; and Other BMPs. The fundamental physical, chemical, and biological properties associated with these BMPs make them effective for both for TN and TP reductions.

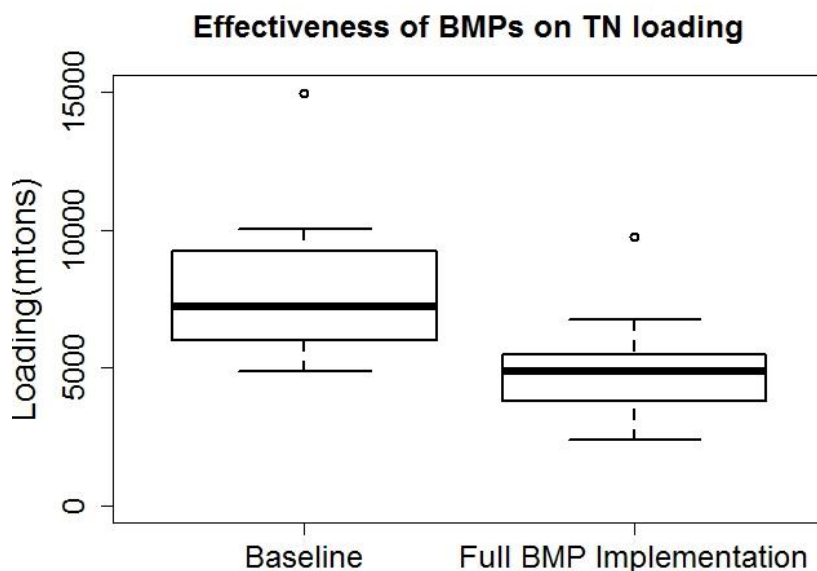


Figure 1. Box plots comparing the EAA TN loading from the “baseline period” (1980-1988) with the period of “full BMP implementation” (1996-2014). The TN loading decreased from an average of 8,184 metric tons to an average of 4,848 metric tons after BMP implementation, a reduction of 40.4%. For more details on this analysis, please see Chapter 2.2.

1 BACKGROUND

The Dept. of Agriculture and Consumer Services (DACS) Office of Agricultural Water Policy's mission is "to help ensure the future of Florida agriculture while conserving the State's natural resources". A primary component of achieving this objective is the development and implementation of agricultural Best Management Practices (BMPs), which are a series of practical, cost-effective actions that agricultural producers can take to benefit water quality and water conservation while maintaining or even enhancing agricultural production.

The Office of Agricultural Water Policy (OAWP) has, by rule, adopted agricultural BMPs for Citrus Groves; Vegetable and Agronomic Crops; Container Nurseries; Cow/calf Operations; Equine Operations; Sod Farms; Specialty Fruit and Nut Operations; and Conservation Plans for Specified Operations. These comprehensive BMP manuals are available at:

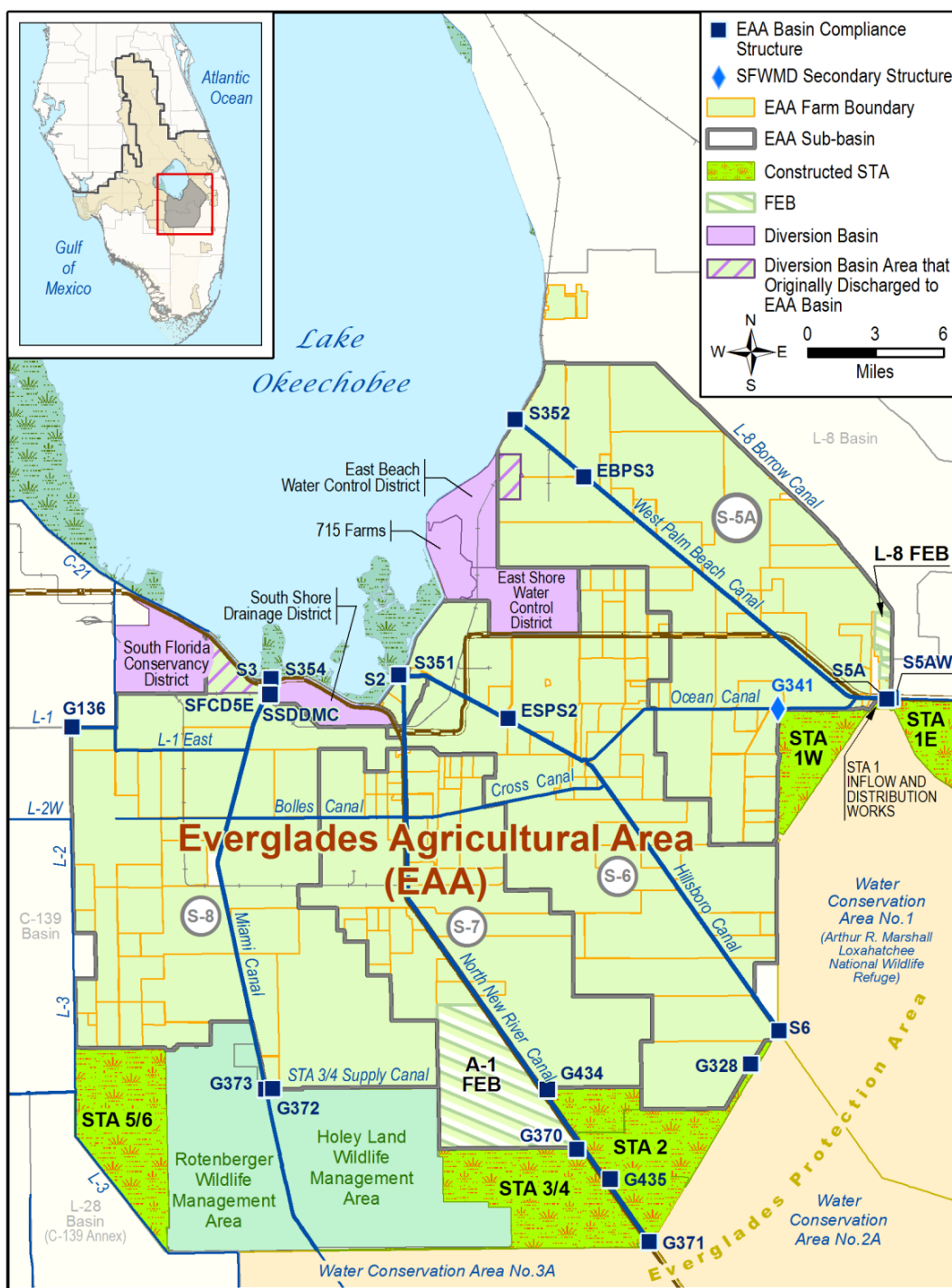
<http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Water-Policy/Enroll-in-BMPs/BMP-Rules-Manuals-and-Other-Documents>

Florida law provides for agricultural producers to reduce their impacts to water quality through the implementation of FDACS-adopted BMPs. Implementation of FDACS-adopted BMPs provides a presumption of compliance with state water quality standards, including numeric nutrient criteria.

Under the DACS OAWP strategic goal to "improve and expand agricultural Best Management Practice (BMP) implementation", are action items to "identify past research and support new research that confirms the effectiveness of BMPs" and to "compile and disseminate success stories related to BMP implementation".

The Everglades Forever Act defines "Best Management Practice" or "BMP" as a practice or combination of practices determined by the South Florida Water Management District, in cooperation with the Department of Environmental Protection, based on research, field-testing, and expert review, to be the most effective and practicable, including economic and technological considerations, on-farm means of improving water quality in agricultural discharges to a level that balances water quality improvements and agricultural productivity.

In the case of the Everglades Agricultural Area (EAA, see **Figure 2**), agricultural BMPs are required by Chapter 40E-63, F.A.C. These BMPs include Nutrient Control Practices; Water Management Practices; Particulate Matter and Sediment Control; Pasture Management; and Other BMPs. It was required by Everglades Forever Act that these BMPs result in a 25% reduction in TP compared with the baseline time period of 1980-1988. Note that Total Nitrogen (TN) was not addressed by this legislation.



1.1 PURPOSE

The purpose of this report was to analyze the effectiveness of EAA BMPs for TN load reductions, consistent with the OAWP goal of confirming BMP effectiveness.

1.2 REGULATORY REQUIREMENTS

Chapter 40E-63, F.A.C., requires that the SFWMD establish a regulatory source control BMP program for the EAA, as implemented through the Works of the District permitting program. The program requires permits that include BMP plan implementation and water quality discharge monitoring plans by permittees in the EAA.

An Everglades Works of the District (EWOD) Permit is required of landowners or entities within or discharging to drainage basins in the Everglades Agricultural Area (EAA). An EWOD Permit is an approval of a Best Management Practices (BMP) plan, and of a discharge (water quality and quantity) monitoring plan where applicable. The goal is to achieve a 25-percent reduction in phosphorus loads from the EAA Basin as a whole. As part of permit approval, SFWMD evaluates whether the proposed activity will:

- Result in a discharge that is consistent with the overall objectives of the District;
- Not be harmful to the water resources of the District;
- Constitute a feasible BMP Plan;
- Include, where required, a feasible Discharge Monitoring Plan; and
- Be granted all other necessary District approvals.

To be in compliance, the EAA Basin is required to achieve a 25 percent reduction of the total phosphorus loads discharged in stormwater runoff when compared to the pre-BMP baseline period, as defined in the Everglades Forever Act, by using specific methods defined within Chapter 40E-63, F.A.C. The specific procedures for determining EAA and C-139 basin compliance, basin-level data collection efforts and farm-level discharge monitoring plans are outlined in Appendix 4-2 of the South Florida Environmental Report.

The SFWMD collects water quality monitoring data from the EAA at discharge locations to evaluate the overall effectiveness of the BMPs in achieving and maintaining compliance with the total phosphorus load reduction requirements. The District also performs site visits to verify BMP implementation and compliance with permit conditions.

Research and demonstration projects are required by statute in the EAA to investigate and improve BMP effectiveness and design. These projects are conducted by the SFWMD in cooperation with the University of Florida's Institute of Food and Agricultural Sciences (IFAS) and basin landowners. Investigation to improve the selection, design criteria and implementation of BMPs is ongoing.

2 ANALYSIS OF EAA TN LOADING DATA

2.1 METHOD FOR DETERMINING EAA BASIN COMPLIANCE

Appendix A3, incorporated by reference into Chapter 40E-63, F.A.C., sets forth the procedures the SFWMD will follow to determine whether the EAA Basin has met the goal of reducing total phosphorus (TP) discharged by 25 percent, under any set of hydrologic conditions that could arise, after installation of farm-level BMPs. The determination requires calculation of future TP load leaving the structures from the EAA (**Figure 3**).

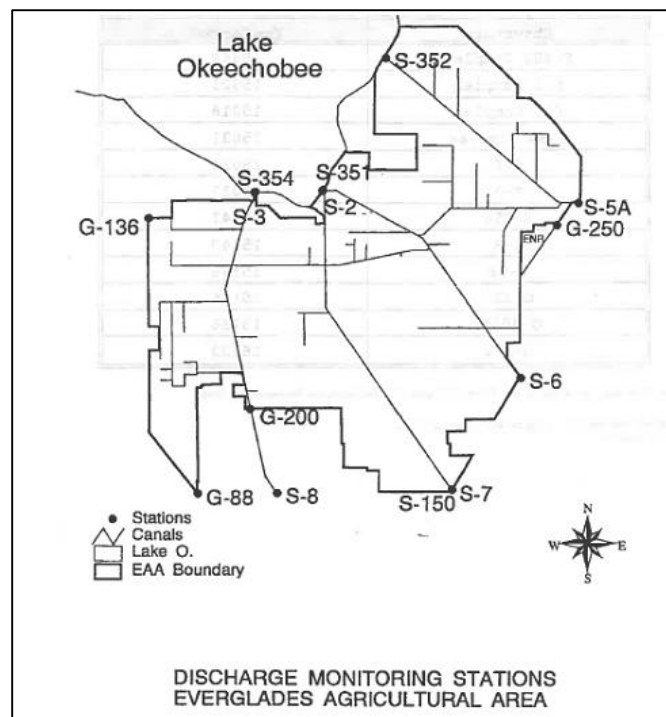


Figure 3. Monitoring stations used to determined compliance with the Everglades Forever Act.

The load is defined as the amount of phosphorus carried past a monitoring point by the movement of water, and therefore, water quality concentrations and water quantity (flow) are required to calculate the phosphorus load discharged from a monitoring point. Data on water quality and quantity at the EAA structures were received from SFWMD, as described in Chapter 4 of the South Florida Environmental Report (SFER 2015). The methods and equations used for the load calculations, which have been

automated by a computer program in FORTRAN language, are outlined in Appendix A3.1, Chapter 40E-63, F.A.C.

Although Chapter 40E-63, F.A.C., specifically discussed TP load calculations, the TN calculations presented below followed the same procedure.

2.2 ANALYSIS RESULTS: BMP EFFECTIVENESS FOR TN REDUCTION

As shown in **Figure 1**, TN loading from the EAA decreased from an average of 8,184 metric tons during the baseline period (1980-1988) to an average of 4,848 metric tons after full BMP implementation (1996-2014), a reduction of 40.4%. This reduction in TN was statistically significant, as determined by a Welch's t-test ($t = 3.0106$, $p = 0.0126$). In **Figure 1**, the boxes represent the upper 75th percentile and lower 25th percentile of the flow weighted, annual TN loadings. The whiskers represent the upper and lower 95th percentile of the data. The bold line in the box is the mean. Welch's t-test was used for this analysis because it is able to compare two data sets of unequal variance and unequal observations.

Besides showing substantial reductions in TN, **Figure 1** also shows a reduction in the year-to-year variability in the data between the baseline period and the period of full BMP implementation. The reduction in data variance was statistically significant, using an F test ($F = 3.2886$, $p = 0.0342$). This suggests that the application of BMPs was associated with a more consistent EAA discharge, of better water quality.

The TN loading data by water year, compiled since 1980, is shown in **Table 1**. The TN load reduction in the EAA over time, as compared to the baseline period, is presented in **Figure 4**. Note that since 1996 (beginning of the full BMP implementation period), the 5-year rolling average TN loading has been 25% to 50% lower than the average TN loading measured during the baseline period (1980-1988). The pattern of TN reduction over time has been similar to the reductions observed in TP (see **Figure 5**).

Table 1. TN loading by water year in the EAA.

Water Year	Observed TN Load (mt)	Predicted TN Load (mt)	Percent TN Load Reduction	Annual Rainfall (inches)	Annual Flow (103 ac-ft)	Annual TN FWMC (mg/L)	Baseline and BMP Status Timeline	
1980	10032	9484	-5.8%	53.5	1162	7.0	Baseline Period	Pre-BMP Period
1981	4851	4436	-9.3%	35.1	550	7.1		
1982	8956	7415	-20.8%	46.7	781	9.4		
1983	14943	13216	-13.1%	64.4	1965	6.1		
1984	7213	8348	13.6%	49.8	980	5.5		
1985	5981	5549	-7.8%	39.7	824	5.5		
1986	7194	8749	17.8%	51.2	1058	5.3		
1987	9230	9003	-2.5%	52.0	1286	5.8		
1988	5258	6521	19.4%	43.4	701	5.7		
1989	5894	5544	-6.3%	39.7	750	5.9		
1990	3875	5660	31.5%	40.1	552	4.9	Partial BMPs	
1991	4307	8511	49.4%	50.4	707	5.2		
1992	4269	7692	44.5%	47.6	908	3.7		
1993	7591	12252	38.0%	61.7	1639	3.8		
1994	4190	8536	50.9%	50.5	952	3.4		
1995	9389	14214	33.9%	67.0	1878	4.0		
1996	6730	10580	36.4%	56.9	1336	4.0		
1997	4893	9015	45.7%	52.0	996	3.9		
1998	9756	10316	5.4%	56.1	1276	6.0		
1999	5122	6491	21.1%	43.4	833	5.0		
2000	6097	10559	42.3%	57.5	1311	3.8		
2001	3081	4805	35.9%	37.3	667	3.8		
2002	4938	7779	36.5%	49.1	1071	3.6		
2003	4120	6786	39.3%	45.5	992	3.4		
2004	4334	7114	39.1%	46.8	961	3.7		
2005	6605	8101	18.5%	51.0	1190	4.5		
2006	5187	7598	31.7%	50.1	1034	4.1		
2007	3418	4459	23.3%	37.2	727	3.8		
2008	3054	6766	54.9%	47.0	619	4.0		
2009	4532	5926	23.5%	43.7	877	4.2		
2010	5735	11063	48.2%	61.9	1079	4.0		
2011	2379	5509	56.8%	42.0	517	3.7		
2012	2843	6094	53.3%	44.4	546	4.2		
2013	4414	8490	48.0%	53.5	884	4.1		
2014	4891	8361	41.5%	53.4	899	4.4		

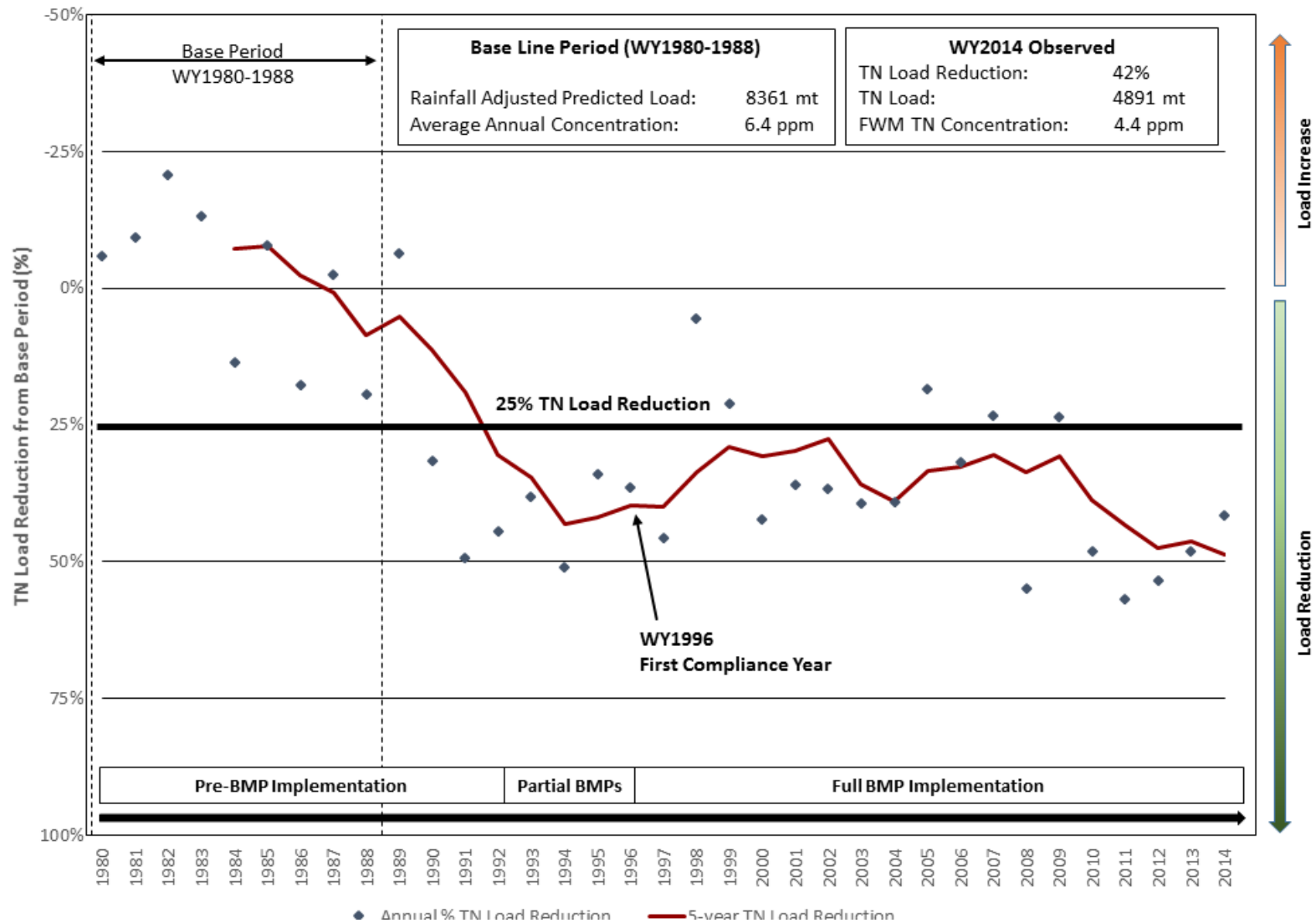


Figure 4. TN load reduction in the EAA over time.

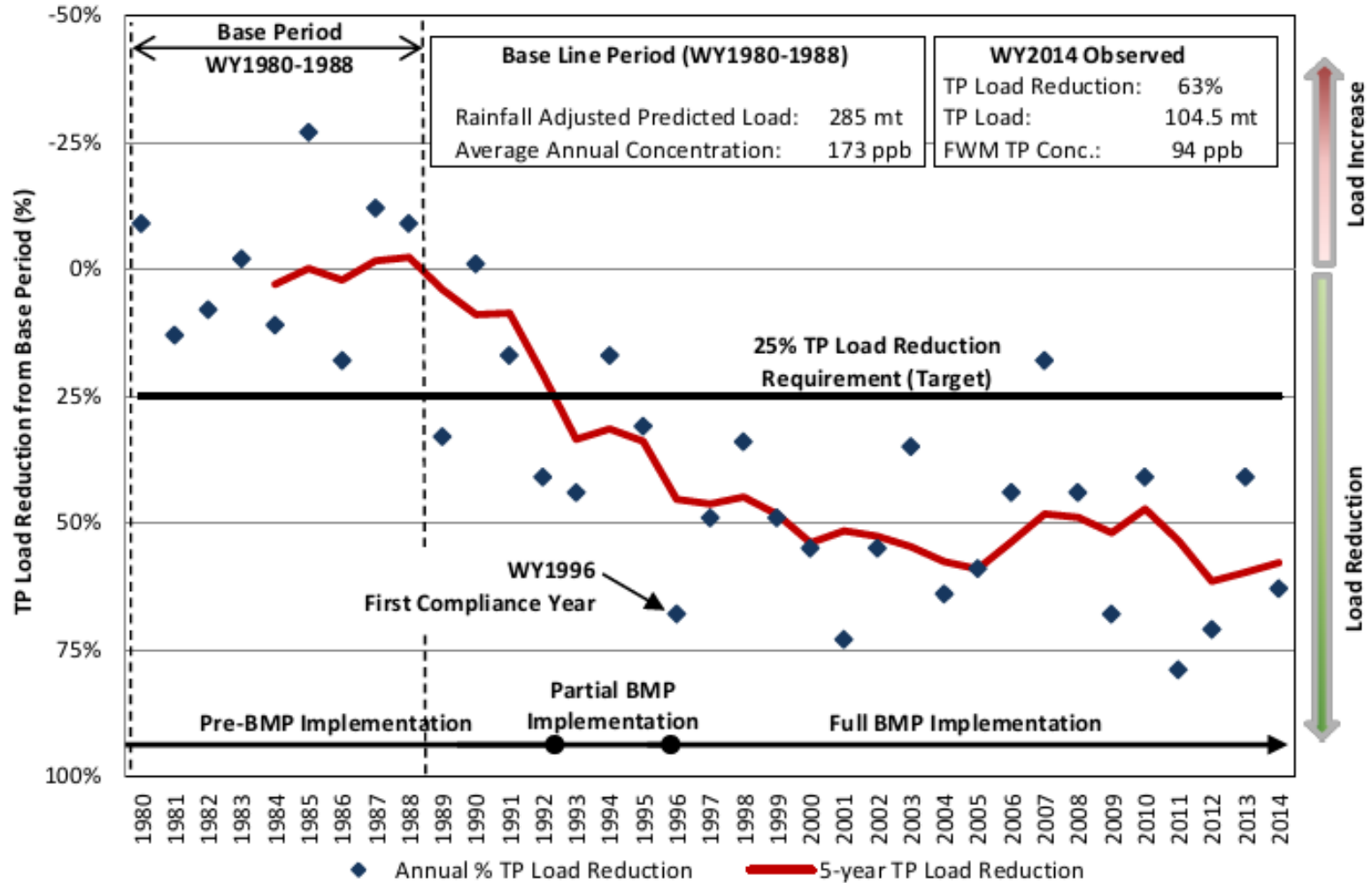


Figure 5. TP load reduction in the EAA over time (from McCafferty *et al.* 2015).

3 DISCUSSION: TN REDUCTION ASSOCIATED WITH BMPs

As mentioned previously, Chapter 40E-63, F.A.C., requires that “Typical Best Management Practices for the EAA Basin” be followed. These BMPs include:

- Nutrient Control Practices;
- Water Management Practices;
- Particulate Matter and Sediment Control;
- Pasture Management; and
- Other BMPs.

Although the BMPs in the EAA were originally implemented to reduce TP (the element causing imbalances of flora and fauna), this chapter examines the BMPs in terms of their effectiveness for TN reductions. As shown in **Figures 1 and 4**, the BMPs are effective for the wide variety of crops grown in the EAA, which include those listed in **Table 2**.

Table 2. Crops grown in the EAA, subject to the requirements of Chapter 40E-63, F.A.C. (personal communication, Dr. Timothy A. Lang, University of Florida Everglades Research and Education Center).

Sugarcane
Rice
Sweet corn
Field corn
Sorghum
Green beans
Sod (St. Augustine grass)
Winter vegetables (lettuces, radish, celery, cabbage, parsley, cilantro)

3.1 NUTRIENT CONTROL PRACTICES

Nutrient Control Practices BMPs include activities such as performing calibrated soil tests to optimize fertilizer use, applying fertilizer for vegetable production in a “banded” manner rather than broadcasting it, and preventing fertilizer spills and the direct spreading of fertilizer into drainage ditches.

Strategies for reducing N and P losses from the organic soils of the EAA focus on lowering fertilization rates based on improved soil-test calibrations and improved fertilizer placement (**Figure 6**) (Lang *et al.* 2005). Fertilizer placement refers to the practice of positioning fertilizer in a specific area within the field (using a variety of banding strategies), generally near the plant roots, in contrast to broadcast strategies which apply fertilizer more or less evenly across the entire field surface (Lang *et al.* 2005). The results of

these BMP efforts to prevent fertilizer from entering farm ditches and canals is very effective in reducing both N and P loading. Banding and nutrient control BMPs can reduce the amount of fertilizer applied to certain crops by 66% compared to broadcast application (Sanchez *et al.* 1990).



Figure 6. Banding application of fertilizer can significantly reduce nutrient loading (from Lang *et al.* 2005)

3.2 WATER MANAGEMENT PRACTICES

Water Management Practices BMPs mainly consist of minimizing water table fluctuations in vegetable and sugar cane fields, and retention of drainage on-farm to reduce overall nutrient losses. This requires the ability to move drainage water to sugar cane or fallow lands for retention and to use some limited ditch or canal storage.

Because the organic EAA soils (histosols) release nutrients when over-oxidized, maintaining the proper level of soil moisture can reduce N and P export from the soils (Wright *et al.* 2012).

Water management BMPs include both **detention** and **retention** (Howell 2013). Detention is temporarily holding water until conditions for release are met, with the object to control discharge rates to reduce impact on downstream receiving systems. Retention is preventing water from discharging into receiving waters. This water is held until it is lost to percolation, evapotranspiration or evaporation (Howell 2013).

Proper water management decisions (**Figure 7**) helps reduce the nutrient load by reducing the volume of drainage water required to adequately drain the field (Diaz *et al.* 2006). This would apply both to N and P.

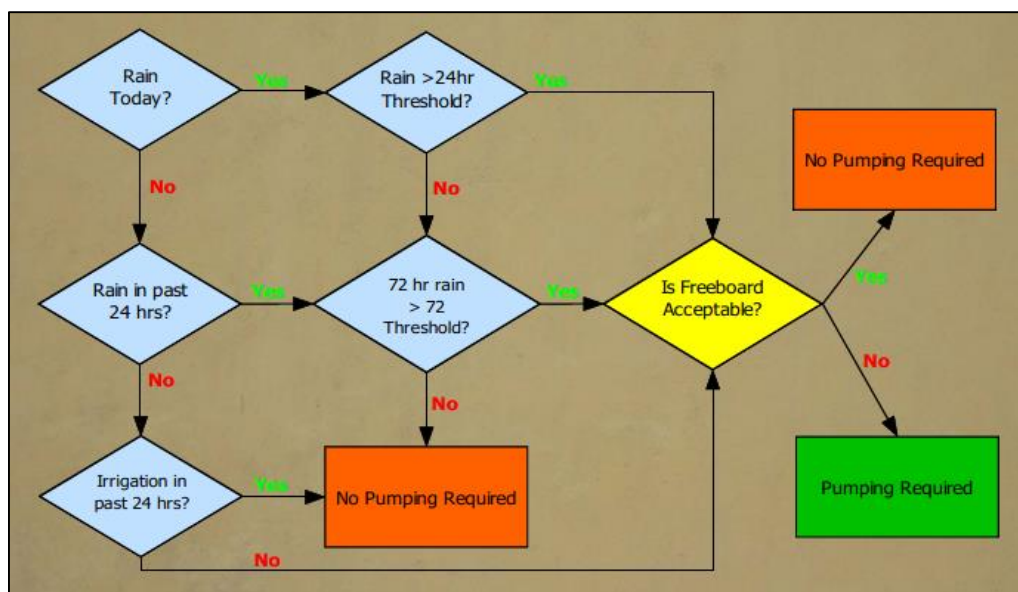


Figure 7. Decision flow chart to assist with implementing water management BMPs (from Howell 2013).

3.3 PARTICULATE MATTER AND SEDIMENT CONTROL

Prevention of particulate matter export from farm fields, coupled with the retention/reuse of ditch sediments, effectively reduces off-site loss of nutrients. This series of BMPs involves planting aquatic cover crops for off-season vegetable production, fallow rotation of sugar cane, coordinated farm cropping patterns, water management practices designed to control particulate matter in the discharge, and recycling of organic ditch sediments back to farm fields.

Leveling of fields, accomplished by laser and GPS guided land-leveling equipment, reduces the potential for soil erosion into field ditches and drainage canals after heavy rainfall (Diaz *et al.* 2006). Leveled fields drain and irrigate more uniformly relative to the soil surface, thus reducing the likelihood of improperly draining and irrigating lower and higher areas of the field. Over-draining the majority of a field to achieve required soil dryness in low-lying areas of the field will unnecessarily add to farm nutrient load by increasing the volume of drainage water required to adequately drain the field (Diaz *et al.* 2006). Note that reducing the volume of farm discharge results in both reduced export of particulate phosphorus and particulate nitrogen. In sugarcane production, fields are usually leveled prior to planting a cover crop such as rice or after cessation of a flooded fallow period. This improves the water management of the rice crop as well as the succeeding plant cane crop (Diaz *et al.* 2006).

Constructing ditch and canal berms minimizes agricultural field surface runoff that may transport soil and associated nutrients from agricultural fields into field ditches and drainage canals (**Figure 8**).

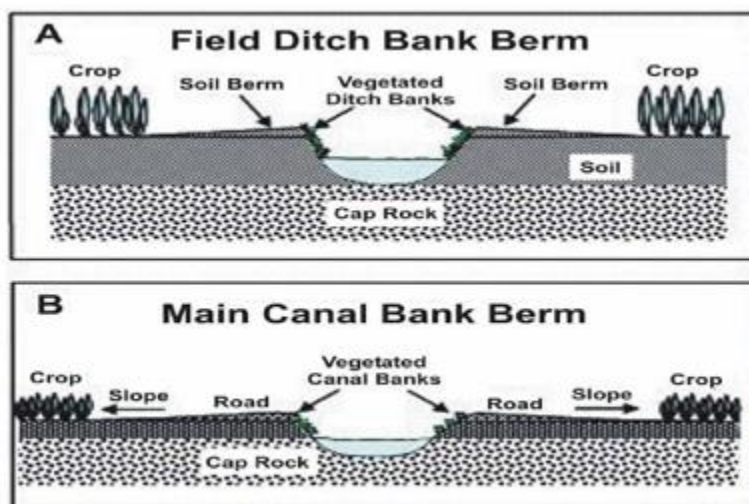


Figure 8. Cross section schematic diagrams of ditch and canal berms (from Diaz *et al.* 2006).

The small mound parallel to the ditch or canal blocks runoff from fields from directly entering the adjacent water, and runoff from a field is then forced to percolate down vertically into the soil, eliminating the transport of soil via sheet and rill erosion (Diaz *et al.* 2006). This would be effective for both particulate P and particulate N.

Canal sediment sumps and traps are constructed by deepening and/or widening a section of a drainage canal (upstream of drainage pump structure), resulting in reduced flow velocity, thereby trapping the heavier sediment material before it is pumped off the farm (Diaz *et al.* 2006). Maintenance and cleaning of sumps is combined with the regular canal/ditch cleaning program of the farm, with the sediment material being placed back into production fields, recycling the nutrients (both N and P) (Diaz *et al.* 2006).

Canal sediment removal, especially near control structures, is an essential practice to eliminate sediment material that has accumulated in the canal systems (Diaz *et al.* 2006). If these sediments are not removed, they have the potential to be transported off the farm during drainage events, resulting in both TN and TP loading downstream.

Slowing and preventing the over-draining of fields close to the farm drainage station involves the installation of water control structures (culverts with riser boards) in field ditches located near the drainage station. Effective use of these small water control structures reduces the amount of drainage water leaving the fields near the pump station, reducing the need to over-drain fields closest to the pump station in order to achieve drainage from fields that are located farther upstream from the drainage pump station (Diaz *et al.* 2006). Note that reducing the volume of farm discharge results in both reduced export of particulate phosphorus and particulate nitrogen.

A cover crop, as defined by Natural Resources Conservation Service, is “grasses, legumes, forbs, or other herbaceous plants established for seasonal cover and conservation purposes.” A cover crop provides soil cover to minimize soil loss to erosion from wind or water. The planting of cover crops on fallow fields is

a sediment control BMP that has been approved for implementation in the EAA. Flooded field crops such as rice and flooded fallow fields have been proven to be very effective in reducing soil losses due to wind and water erosion, and in addition, stop soil oxidation (Diaz *et al.* 2006). Because the organic soils of the EAA contain both P and N, cover crops help prevent loss of both elements.

The installation of culverts that join field ditches with adjoining canals at a calculated and measured height above the ditch or canal bottom is a BMP designed to reduce the chance of sediment transport during drainage events and consequent discharge off farm. This sediment control practice can be combined with the construction of a sump at the entrance of the culvert to take advantage of sediment trapping in the sump, with the organic sediments all periodically recycled back onto the production fields (Diaz *et al.* 2006).

By protecting ditch and canal banks with a vegetative cover, the amount of runoff and erosion from bank sediments will be reduced (especially during rain events), thereby reducing the amount of nutrient-rich sediments being discharged downstream (Diaz *et al.* 2006). This would be effective for both particulate N and P.

Results from sediment transport and floating aquatic plant P cycling studies provide strong evidence that floating aquatic plants may be the principal source of exported particulate P from EAA farms (Stuck *et al.* 2001; Daroub *et al.* 2003). Therefore, limiting the growth of floating aquatic vegetation in main canals, especially upstream of drainage structures, is a very important particulate and sediment control practice (Diaz *et al.* 2006). Readily suspended flocculent organic material (plant detritus), which is high in N and P content, may be controlled by an aggressive floating aquatic vegetation control and removal program, thereby reducing export of both nutrients.

3.4 PASTURE MANAGEMENT

Pasture management BMPs are designed to prevent cattle waste from entering aquatic systems, and consist of providing cattle with reduced phosphorus feed, properly locating watering, holding, and feeding sites, and judiciously managing grazing rotation. Preventing animal wastes from entering ditches and canals would effectively reduce both N and P loading.

3.5 OTHER BMPs

Chapter 40E-63, F.A.C., allows for the utilization of other BMPs proposed by an applicant (and approved by SFWMD) that reduce phosphorus loads discharged from an applicant's property. Farmer proposed BMPs must include, at minimum, a description of the BMP and how it will be implemented, the BMP's applicability to the specific crop and soil, a description of how implementation will be documented, and a description of any training that may be necessary to carry out the BMP.

4 CONCLUSIONS

The TN loading exported from the EAA has decreased from an average of 8,184 metric tons per year during the “baseline period” (1980-1988) to an average of 4,848 metric tons per year during the period of “full BMP implementation” (1996-2014), a reduction of 40.4%. The reduction in TN loading was determined to be statistically significant by a Welch’s t-test ($t = 3.0106$, $p = 0.0126$). Besides showing substantial reductions in TN, there was a statistically significant reduction in the year-to-year variability in the data between the baseline period and the period of full BMP implementation. This suggests that the application of BMPs was also associated with a more consistent EAA discharge, of better water quality. Since 1996 (beginning of the full BMP implementation period), the 5-year rolling average TN loading has been 25% to 50% lower than the average TN loading measured during the baseline period (1980-1988). The pattern of TN reduction over time has been similar to the reductions observed in TP. Typical Best Management Practices for the EAA Basin consist of Nutrient Control Practices; Water Management Practices; Particulate Matter and Sediment Control; Pasture Management; and Other BMPs. The fundamental physical, chemical, and biological properties associated with these BMPs make them effective for both for TN and TP reductions.

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